Research on a comprehensive and transferable ritual semantic model to auto building design in historical games

ritual semantic model historical games

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Feudal historical buildings with ritual elements are the basic scenes of many excellent games, However,researches on design methods for factual historical buildings in game are still out of demands both on precision and migration capability.Aiming at this problem,this paper deeply reflects on the semantic or ontology modeling of ritual elements and their integration model with the game engine and PCG.firstly,we comprehensively provides a ritual semantic model that can be used for automatic generation of ancient buildings in game historical scenes. Secondly,we designed the ritual semantic model to provide the loose coupling capability with the game environment and building system based on the ontology design pattern.Thirdly,through the analysis of the ritual semantic system of Style Lei, the experimental verification of the ritual semantic model is carried out, and the migration capability of the ritual semantic model is proved by comparison.The models and experiments proposed in this paper and even the analysis of the ritual elements in the Chinese style Lei building system can provide useful references for both game scene auto design and related researches.

CCS CONCEPTS • Knowledge representation and reasoning • Ontology engineering

Additional Keywords and Phrases: Ritual Semantic Model,Auto Building Design,Historical Games,Comprehensive And Transferable

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1 INTRODUCTION

Feudal historical buildings with ritual elements are the basic scenes of many excellent games, and it is of great significance to establish a auto design method for ritual architecture construction. AAA Games increasingly take place in highly detailed virtual worlds, often featuring complex historical building scenes. Notable recent examples include Assassin's Creed, Elder Scrolls and romance of the three kingdoms series(as Figure 1), where players explore extensive ancient cities filled with detailed and visually appealing facades, such as the Indiana Jones and Lara Croft: Tomb Raider from medieval Florence to Paris and London, from the hot ancient Egyptian city to the cold Viking village, or to the humid Angkor Wat, the game companies have produced tens of thousands of historical buildings with high fidelity, which have been well praised by players. Academics in virtual heritage also appear to have accepted games with factual reconstructions of history as viable ways of allowing more people to explore and relive historic events and heritages(Champion, 2009).

Figure 1: Typical historical game scenes

However,researches on design methods for factual historical buildings in game are still out of demands both on precision and convenience.

1.1 STATE OF THE ART

1.1.1 The ontology researches of historical buildings lacks the content of ritual system

The organising, sharing and digitally processing feudal historical buildings' information in game scene can be classified to the development of formal knowledge representation models (ontologies) for the CH(cultural heritage) domain.

Based on RDF(Resource Description Framework) and OWL(Web Ontology Language), the standard data model and ontology language of the Semantic Web, relevant ancient building ontologies such as CIDOC-CRM(Doerr, 2009), the Europeana Data Model and VRA(Visual Resource Association), offer enhanced representation capabilities, but also support for inference, querying and interlinking the voluminous, diverse and heterogeneous Cultural Heritage (CH) information which is mainly available in museums, art galleries and other CH institutions. And the purposes of

organising CH ontology data and enabling the development of enhanced data services are to improve effect of exhibition and conservation to the physical collections and their digital counterparts. Semantic Web ontologies are the most widely used for CH, mainly because of their enhanced expressiveness, allowing to obtain and resemble complex semantic relationships among CH entities through the Web(Liu and Bikakis et al., 2017).Europeana(Valtysson, 2020), an EU-funded initiative which aims at collecting semantic metadata about various national cultural heritage sets and publishing their integrated version in a machine understandable way compliant with Linked Data principles(Cacciotti and Valach et al., 2013).MIDAS(England), a British cultural heritage standard for monument inventories, and The Core Data Standard for Archaeological Sites and Monuments(Carlisle and Avramides et al., 2014) translate their documentation standards to CIDOC CRM compatible ontology providing a framework for documenting monuments.(Etim, 2019) discusses ritual ontology in Africa, and proposes religious-related ritual hierarchy and ritual definitions.A more historical scene semantic generation relevant research(Liu and Wu, 2016) presented a rapid rule-based modeling approach to building ancient Chinese architecture which is based on a module semantic rule system abstracted from an official manual of ancient building "the Yingzao Fashi". (Sacco and Liapis et al., 2017) presented a Game Character Ontology (GCO), a light-weight vocabulary for describing character information in video games without any definition about game scene. In general, few ontology directly studies ritual architecture or establish ritual ontology alone, especially in game field.

Although previous ontologies offer a solid methodological and technical background from which CH information figures out, their representation is nevertheless not rich enough for designing the multi-faceted ritual domain of feudal historic buildings, especially as far as the relevance of game scenes auto-generation in the perspective of heritage realistic reproduction is concerned(Cacciotti and Valach et al., 2013).

1.1.2 High-precision modeling methods for historic buildings based on 3D scanning and manual modeling are of high cost

Post-processing in game environment with the data of high-precision 3D scanners by professional tech-artists is a reliable way to reproduce feudal historical buildings from reality with high precision. However, this way for game scenes of high-precision historical building requires a lot of financial investment and personnel time cost, and the related data and personnel skills is hardly reusable. Taking Ubisoft as an example, in the production of Assassin's Creed, a large number of high-precision models are used for high-precision laser scanning and manual refinement, such as the Cathedral of Notre Dame in Florence (Cattele di Santa Maria), and Notre Dame de Paris in Paris. Template. However, according to USA TODAY(Snider, 2019), scene designers had spent 2 years restoring the original appearance of Notre Dame de Paris, and it was accurate to every stone. In order to improve the efficiency, approaches for point-cloud segmentation and primitive shape detection should be employed. The most commonly used methods are: Least Squares(Wolf and Ghilani, 1995), Least Median of Square(Massart and Kaufman et al., 1986), and RANdom SAmple Consensus (RANSAC) (Jin and Lee, 2019). Many researchers exploited these methods in architecture reconstruction and 3D modeling. (Liu and Wu, 2016) provided an adaptive approach for primitive shape extraction from point clouds. (Früh and Zakhor, 2004) presented a system to map cities in 3D using two 2D laser scanners mounted on a truck. (Gao and Shen et al., 2018) summarized rules to extract solid geometry components from point clouds of elements in traditional Chinese buildings. (Huang and Brenner et al., 2011) presented a generative statistical approach to automatic 3D building roof reconstruction from airborne laser scanning point clouds.But these

high-precision manual or computer-assisted modeling methods obviously cannot be extended to all historical game scenes not to mention the ritual enhanced building reconstruction.

1.1.3 BIM-based historic building modeling method not integrated with games

Building information modelling(BIM) and semantic web technologies are two technologies that are often used for the documentation of the built environment and of cultural heritage resources. (Pauwels and Bod et al., 2013) combined the application of BIM software and semantic web technologies to a case study: the Book Tower in Ghent, Belgium,which shown the recorded semantic information can be essential to manage a recovery plan with cultural diversity and environmental sustainability.(Bonsma and Bonsma et al., 2018)proposed a Heritage-BIM ontology to represent all the complexity of the related context in term of ancient architectural techniques and components, important events related to the history of the building / site and all the data that define the actual value of the monument in term of historical heritage. According to Historic England (Thouki, 2019)and (Arayici and Egbu et al., 2012)custom semantic content creation is a requirement for BIM projects, since usual construction object libraries are related to new-build rather than historic building components. However, the inclusion of BIM objects from very different sources (creators, skills, purpose and context) is problematic for information consistency.Thus to facilitating the international exchange of heritage information ISO 128 (graphical representation of objects on technical drawings)(Nopnakorn, 2003), ISO 16739:2013 (IFC,Industry Foundation Classes for data sharing)(Markič and Donaubauer et al., 2018), ISO 1302:2002 (surface texturing in technical product documentation)(Qi and Jiang et al., 2013), ISO 21127:2014(Beretta and Alamercery et al., 2019) and CityXml(Li and Tang et al., 2017)(reference ontology for the interchange of cultural heritage information) needs to be considered. In the domain of design and construction of buildings, the interoperability issue is closely tied to the notion of interpretation(Li and Tang et al., 2017). Because of different purposes,the semantic interpretation stored by the BIM system(s) used to document the artefact, and the interpretation by the end designer of the cultural heritage artefact in game scenes often makes the ontology self-contradictory.

1.1.4 The researches on Procedural content generation (PCG) of buildings in games lack the transferable content of ritual elements

PCG refers to the creation of game content automatically (or semi-automatically), through algorithmic means. Attempts at generating game content procedurally have a fairly long history as PCG aspects appear in games such as Rogue (Toy and Wichman et al., 1980), Diablo(Entertainment, 1996) and Elite (Braben and Bell, 1984).The first comprehensive declarative semantic model of a game world useful for PCG was proposed by Smelik(Smelik and Tutenel et al., 2011), who defined four levels of abstraction of modelled game objects: geometric objects level (including 3D geometric meshes, textures, etc.), semantic objects level (represented by a set of generated objects and their features), structure level (including feature extent and structural objects), and specification level (outline shape and semantic attributes). (Bontchev, 2017) presented A semantic consistency moderator to ensure the maintenance of the consistency of the semantic model of the content.In the fifield of automated generation of building facades, L-systems were among the first techniques to be proposed(Coelho and Bessa et al., 2007). These rewriting systems create buildings by manipulating an initial arbitrary ground plan (a lot shape) with transformation and extrusion modules.To obtain more interesting building shapes, several approaches have been devised. (Wonka and Wimmer et al., 2003)introduced the concept of split grammar, a formal context-free grammar designed

to produce building models. The split grammar resembles an L-system where shapes are primitive elements rather than symbols. In recent years, a more specialized approach, the CGA shape grammar, has been applied to building facades(Silva and Müller et al., 2013). Shape grammars have been used and described before, especially in the architectural domain(Li, 2001; Tepavčević and Stojaković, 2012). Architects have described shape grammars as languages of design, supported by a vocabulary of shape rules. Shape rules are specified as spatial relations,with context-sensitive rules which allow the possibility of modeling roofs and rotated shapes. They start with a union of several volumetric shapes (the building boundary) which is divided into floors. The resulting facades are further subdivided, through shape rules, into walls, windows and doors. Epic Games also included shape grammars in their commercial game engine,Unreal Engine 3(Dormans, 2010), a procedural artist-driven tool for constructing buildings used in the development of city-based games(Tutenel and Smelik et al., 2011). The procedural system uses rulesets, similar to shape grammar rules, to split facades into scopes and automatically place meshes on them(Dokter, 2014). However, the focuses of all these building relevant PCG are not on the automatic generation of ancient buildings, especially in absence of ritual elements,which can not be described in shape grammar like semantics.

1.2 GOALS AND RESEARCH QUESTIONS

Although there is a lot of work that appears to be related to the automatic generation of ritual buildings in games, there is still no direct research on transferable method that can alleviate the enormous burden of ritual buildings creation and make it easier to tailor content to game designers, especially considering the international nature of ritual elements.

Aiming at this problem, this paper deeply reflects on the semantic or ontology modeling of ritual elements and their integration model with the game engine and PCG.

Based on the existing researches on the semantics of PCG building or BIM rules, a transferable generative ritual semantic model for game historical buildings is established.This approach is suitable for modeling each type of ritual buildings in game scene by assembling ritual elements(as Figure 2). The fundamental difference between our approach and previous work is that we design a uncoupling ritual semantic system and apply it in auto generation of ancient ritual buildings in a game environment according to Chinese “style LEI” ritual system as am example. Moreover, the Chinese “style LEI” ritual semantics also apply to a Japanese ancient building as a proof of its migration capabilities

The most important step of the approach is to abstract the ritual semantic elements and design uncoupling layer to ensure the compatibility with various buildings. In order to do that, we must analyze the ritual systems, especially the “style LEI” one and formalize them into semantic definition.

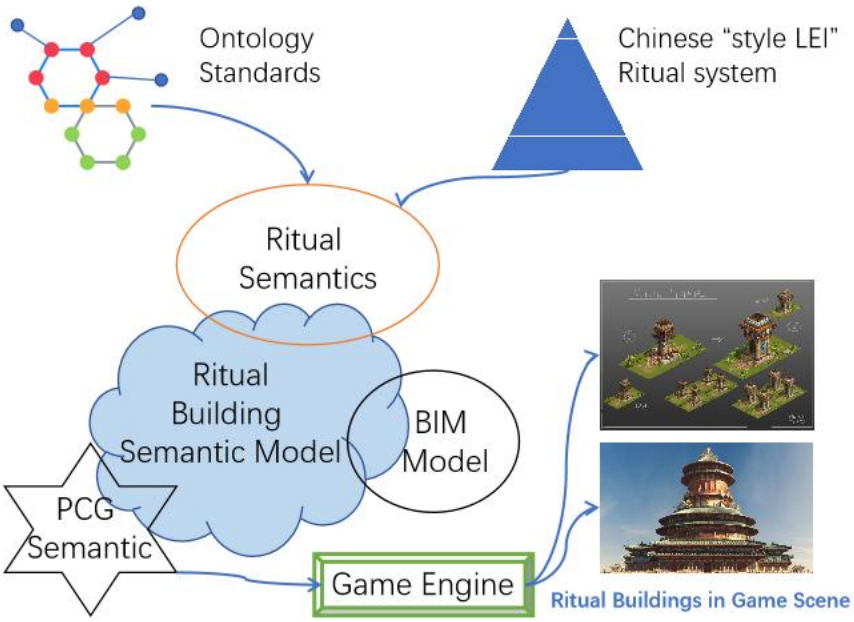

Figure 2: The framework of this research

The article is organized as follows. Section 2 describes the ritual systems and characteristics of ancient Chinese "style LEI" ritual system. The compatible design according to ontology design pattern for ritual construction of ancient buildings are presented in detail in Section 3. Section 4 presents some experimental results are shown to demonstrate the efficiency and migration capability of the approach. We discuss our results and suggestions for future work in Section 5.

2 RITUAL SYSTEM AND SEMANTICS

2.1 Universal Ritual System

T.O Ranger (Ranger and Kimambo, 1972) sees ritual as constituted of four structures thus:

1)Symbolic structure—that ritual is an aggregate of symbols, a totality of which aid adequate understanding of human society.

2)Value structure—that ritual is expressive of authoritative message about crucial values and relationship between values.

3)Telic—that sees ritual as performed for the sake of an end; designed to have effect on the people and bears the concern of posterity and future generations.

4)Role structure—implies ritual as the product of interaction of different human action representing different social categories/classes and not a product of individual ingenuity and initiative. So, it transcends individual/subjective interest of those who take part in it but tends to embrace the common good(Etim, 2019).

The fundamental purpose of a ritual system is to make legal explanations and arrangements for the rationality and authority of feudal hierarchy, and its essence comes from the symbolic distribution of rights. Most countries in the world have gone through a long feudal era(Topolski, 1981). From 475 BC to 221 BC, China entered a feudal society that lasted for nearly 2,000 years(as Figure 2). The imperial administration made detailed regulations on the architectural

styles of different feudal grades , called as ritual buildings. After the collapse of the Western Roman Empire in 476) to the French Revolution in 1789, the feudal lords and the Holy See in various countries also marked the feudal level through building materials, arch spans, building heights, etc. The Middle East has been in Saudi Arabia and other places since the Arab Empire in the 7th century AD(Etemad, 2017). The feudal chieftain system is still preserved, and the feudal hierarchy is also expressed through the height of the dome and the size of the indoor garden. Similarly, countries such as India and Japan have their own ritual rules of architectures.In general, ritual systems in most feudal countries define important elements of buildings in common whatever it is.

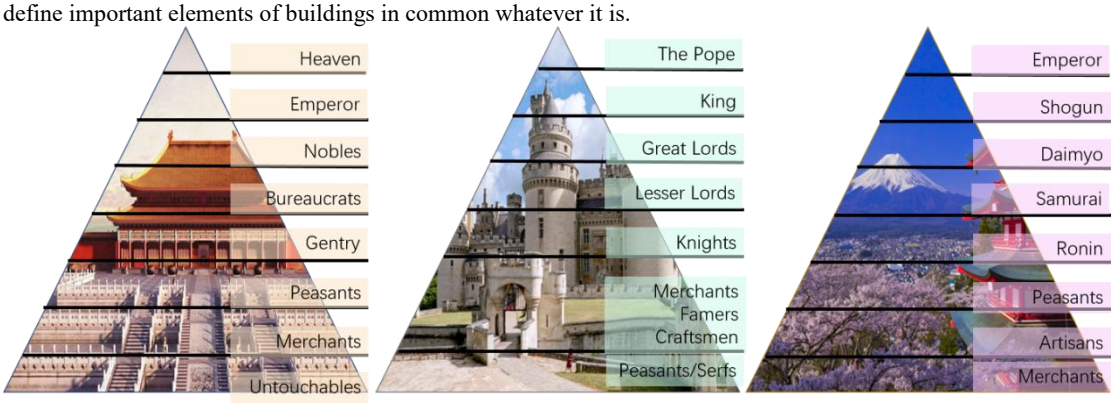

Figure 3: Feudal hierarchies in China, Medieval Europe and Japan

Although there are many differences in the source of feudal ritual system between countries and cultures, such as the "God and my right" (Britain, France), the "Heaven and my right" (China, Japan), and the system of feudal ritual levels is also different, for example, each country has different royal titles, official bureaucratic position and other ritual hierarchy (Harem, Vassals) systems, but the characteristics of ritual permeating all elements of feudal social architecture were the same.

2.2 Characteristics of Ancient Chinese "style LEI" ritual buildings

During the thousands of years evolution of Ancient Chinese architecture, the architecture in Qing dynasty has developed a comprehensive and rigorous methodology and hierarchy. Among all the skilled craftsmen and architects, LEI family has been responsible for the design, construction, and maintenance of the imperial architecture and gardens in Qing dynasty(Jiaojiao, 2004), and the building they designed is therefore called the "style LEI" building(as Figure 4,Figure 5). The architectural manual Qing Dynasty Architecture Method (Example of Qing Gongcheng Zuofa Zeli's Engineering Practice) written by the engineering department of the government stipulate the building hierarchy in which building of different grade have different scale, structure, unit, shape, material. The manual works as guidance of the design and build of the royal buildings and gardens by LEI family. Researchers analyse LEI family and their architecture from a historical perspective based the documents, codices(Shengmei, 2008), models and diaries(Dingkun, 1989).

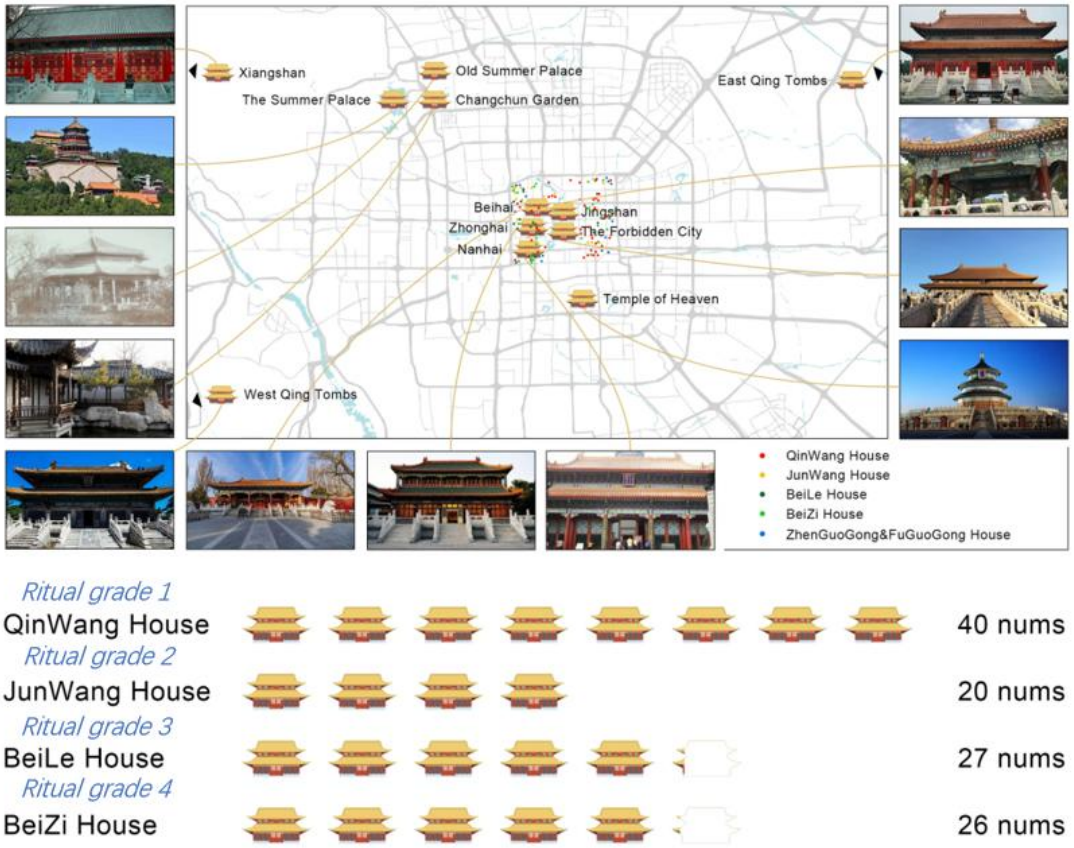

Figure 4 : "style LEI" ritual buildings in urban area of Beijing

Figure 5: "style LEI" ritual buildings and ritual system

The current researches on "style LEI" building mainly focus on the history analysis, literature review, and architectural design method research, as well as it ritual system(Dingkun, 1989; Jiaojiao, 2004; Shengmei, 2008). There are many ritual elements in Style LEI, but they can be classified into 3 types:

1)Ritual space structure. The ritual elements of spatial structure control the spatial layout and basic structure of the building. For example, the area of the building foundation, the spacing and the number of pillars are all specified according to the feudal level.

2)Ritual components. The ritual components may or may not have architectural functions, but they must have distinct 3D structural characteristics. For example, the number of roof beasts is also specified according to the feudal level.

3)Ritual decorations. The ritual decorations are ritual elements decorating other architectural functional components (as Figure 6) without any architectural functions by themselves, and their three-dimensional structure is not very obvious either.For example, architectural color paintings, in which the patterns are also specified according to the feudal level.

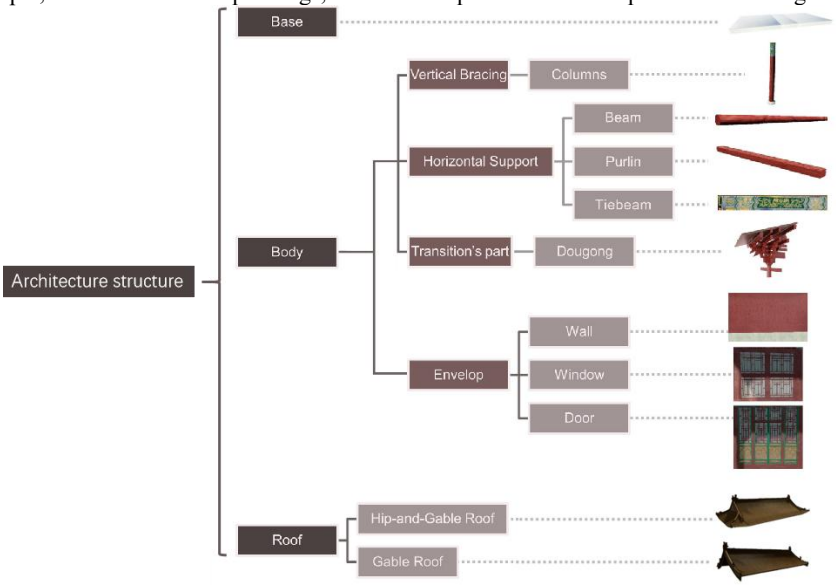

Figure 6: The architectural functional components of "style LEI" building

2.3 Ritual Semantic Model design

2.3.1 Ritual Building Generation Process In Game Scenes

For the sake of simplicity, the question of semantic or ontology modeling of ritual elements and the integration model with the game engine and PCG will be expressed in 4 layers of a runtime environment(as Figure 6). To begin with the semantic compatible design of ritual buildings, considering an building process(area colored in blue in Figure 7) as described by the Building Topology Ontology (BOT) (Rasmussen and Lefrançois et al., 2021)and IFC ontology in BIM(Iadanza and Maietti et al., 2019) area which is admittedly shared by a wide range of the community, it may be adequate to say that an ritual building is a particular kind of bot:Building, an upper class of the OWL Description logics (DL) . And the following questions can be considered:

1)What are ritual buildings? A small set of historical buildings. That notion of ritual building is captured by the class dot:RitualBuilding, which is defined as: “Any inheritance of an dot:building(but not a part of it), which cannot exist without the ritual system and the specific ritual grade, and are temporally and spatially located in a specific feudal dynasty”. In the context of the former “style LEI” survey, features of ritual building are also elements in the domain of buildings.

2)What is the PCG driver? A content generator, which is a particular producer of dot:Building.

3)How is the Ritual Building made? Following a procedure in PCG , which can be considered an individual of IFC:Process which can instantiate a particular sequence of the class bot:RitualElement according to IFC:RitualBuildingConstraints.

4)Where is the IFC:RitualBuildingConstraint made? In a ritual system, that would be represented by several inheritance types of the class IFC:RitualConstraint, which is defined as: “Any elements in a domain, which can be used as a exclusive value for a specific ritual grade. For example, Roof beasts Constraint, pillars Constraint, Paintings Constraint are all subclasses of IFC:RitualConstraints from “style LEI” .

5)When is the bot:RitualElement made? In the PCG driver’s execution, instantiated by an individual of bot:Element and IFC:RitualBuildingConstraint.

6)Which is the result of the building generation? An encoding of a value represented by an individual of dot:RitualBuilding. This encoding can be achieved by asserting all the IFC:RitualBuildingConstraints to the PCG driver by using the instantiated bot:Element(such a bot:Pillar is a simple definition of a structured geometry data including diameter and height as required variables, which may be directly assigned by a specified IFC:RitualBuildingConstraint)

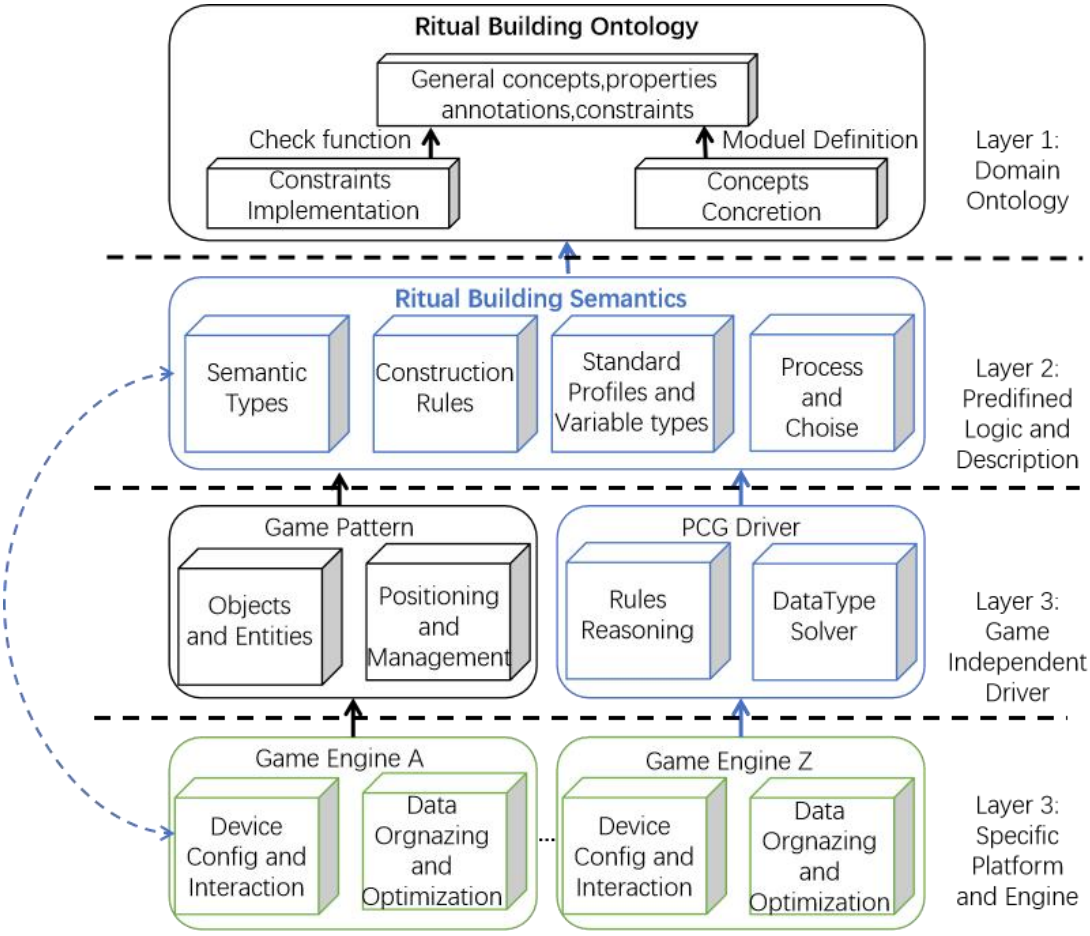

Figure 7: Scope of the Ritual Semantic Model（in blue color）

2.3.2 Decoupling Design Based On Ontology Design Pattern

In order to describe, manage and auto-generate a ritual building appropriately with migration capability, it is necessary to understand stable and abstract parts of the ritual system, so that information on the ritual buildings can eventually be organized 'correctly' everywhere. In this initial decoupling design, ontology design pattern goes through all kinds of relevant information sources to construct a general understanding or a abstract model of the ritual building. For instance, through a critical and comparative literature review, we can investigate whatever elements and constraints (geometrical, structural,colorful,material,spatial, and so forth(Arayici and Egbu et al., 2012)) may be used for a ritual system.

Particular aspects of the building elements and constraints of "style LEI" at hand,and the first question of decoupling design is how this information can be organised and compatible with other ritual system or build system.

In the case of the ritual survey in "style LEI" documents, our decoupling design consisted of the thoughts enumerated below.

1) Does a ritual constraint necessarily apply to a building? No, only if the building has a building element that matches this constraint.

2) What kinds of building elements do ritual constraints affect? All of them,according to the development of archaeology and literature research, in theory, all building elements can be constrained by rituals, because rituals are artificially defined and do not bind to any building entities.

3) Is there an upper limit to the ritual constraints applied to a building? No,the same reason as the previous.

4) Should the generation process of ritual building be defined by ritual semantics itself?No need, in the historical game, PCG already contains the spatial and temporal rules, if in the BIM field, IFC also defines the construction semantics of the building.

5)Whether the ritual semantics need to consider the difference of game engines, for example, some engines express building modules as boundary-surface models, while others are volume models?No need, in game field, PCG's design has taken these game engine differences in consideration, we only need coordinate ritual semantics to PCG's definition.

6)Will the ritual semantics be static in a game scene?No, With the continuous expansion of the game scene and change of the gameplay, it is possible to have multiple feudal dynasties or even multiple countries in one game, and it is necessary to flexibly specify the ritual building system corresponding to the game design.

7)Does a feudal dynasty have only one ritual system?No,from style LEI's research, it can be found that China's Qing Dynasty ritual architecture system has undergone many changes.

From the above thinking,it can be drawn that although the purpose of this research is to automate the generation of ritual building in game scenes, the ritual semantics part cannot be bound to the game engine and building entities,neither the PCG driver, nor can it be necessarily exist statically in one game.Thus, according to the six families of Ontology Design Patterns (OPs) (Gangemi and Presutti, 2009),we choose ontology design patterns(as numbered dash box in Figure 8) three times to uncoupling the ritual semantics from specific game environment.

1)Correspondence OPs to match ritual and building elements.

2)Correspondence OPs to represent ritual building rules through PCG Rules.

3)Reasoning OPs to filter or derive the currently required ritual system.

Under such a ritual semantic design as Figure 8, the ritual elements of the historical buildings in the game scene not only have the execution efficiency and quality of PCG, but also be dynamic and reusable.

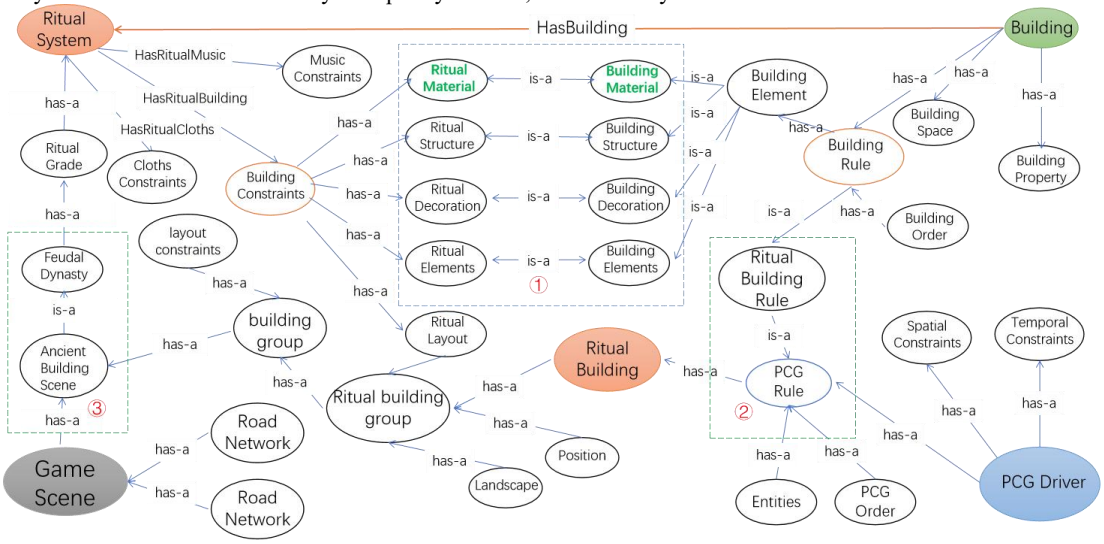

Figure 8: Ritual semantic model based ontology design pattern

According to the design of ritual semantic model, the process applied in the game is as follows:

1). According to the design of the ancient scene of the game, find the corresponding feudal dynasty.

2). Select the ritual grade and find the corresponding ritual system in the feudal dynasty.

3). Obtain the building constraints defined by the ritual system.

4). Configure the basic building elements and their properties in PCG.

5). Match the building elements of ritual constraints with the building elements defined in PCG.

6). Instantiate the ritual building elements through PCG.

7). Position and assemble the combination of ritual building elements through PCG.

3 EXPERIMENTS

According to the semantic design of the ritual system above, we selected the ritual system elements in the style LEI, taking the main hall and the square pavilion as examples, and conducted an experimental test. The experimental environment is Unreal 4.26, the PCG driver is implemented using the blueprint system inside Unreal, and the instantiation of building elements is also realized through the asset management module inside unreal.

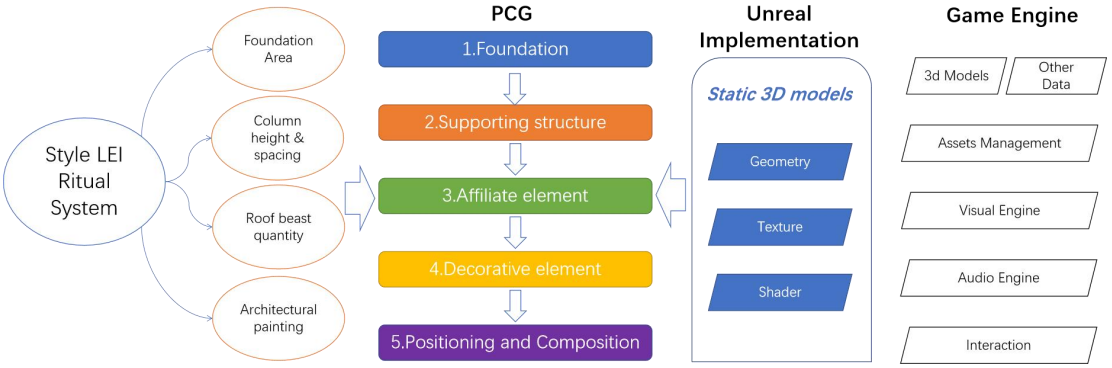

Figure 9: The procedure of the Experiment

The first experimental building object is the main hall, the largest part of the ancient Chinese-style residential suite. The ritual elements of the main hall include 4 items: the area of the foundation; the number and spacing of the pillars; the number of roof beasts; the architectural paintings.

First of all, according to the preset two ritual grades of Qingwang(ritual grade 3) and Baylor(ritual grade 5), the corresponding ritual elements are automatically generated.

Secondly, it is matched by the building element definition in the PCG driver with the geometry and textures.

Third, the overall model of the building is automatically generated through the building combination rules of the PCG driver, which is the same to previous rule based ancient building production.

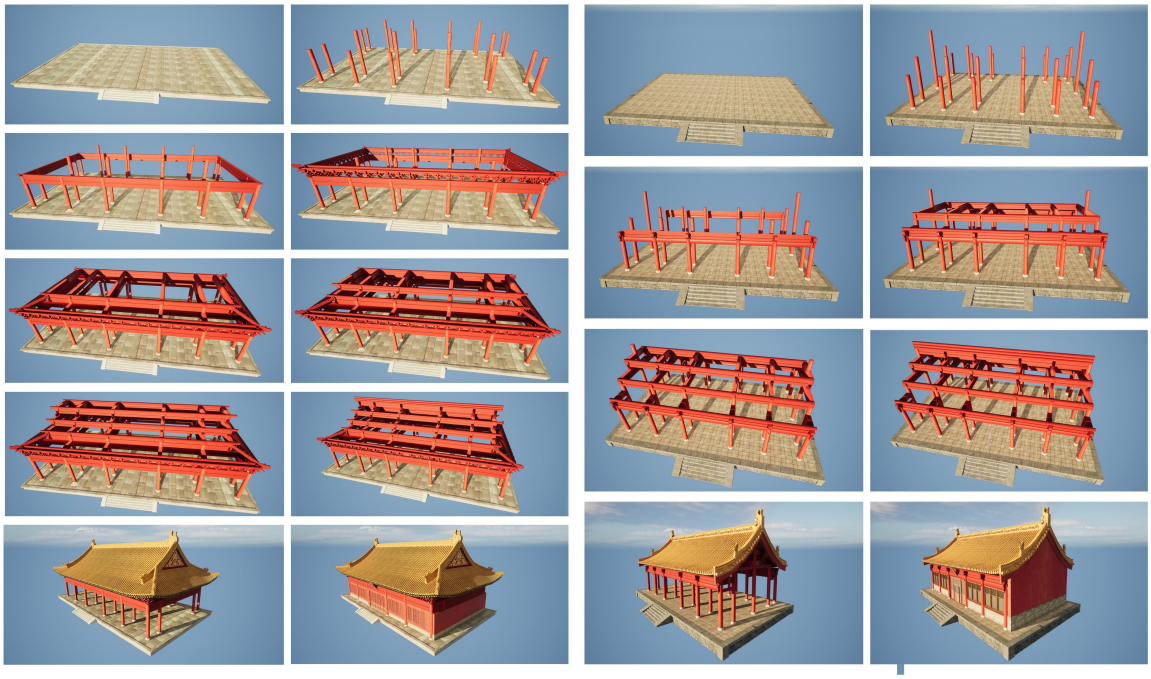

Figure 10: The main halls of Qingwang(ritual grade 3 in the left) and Baylor(ritual grade 5 in the right)

Figure 11: The ritual elements on main halls of Qingwang(grade 3 in the left) and Baylor(grade 5 in the right)

In order to test the reusability and migration capability of the ritual semantic model, we added 2 ritual model migration experiments.

The first one is to change the building type from the main hall to the square pavilion, which is a common leisure building in Chinese classical gardens. It can be seen that the ritual model Constraint and Ritual elements are still correctly matched to their corresponding building elements.

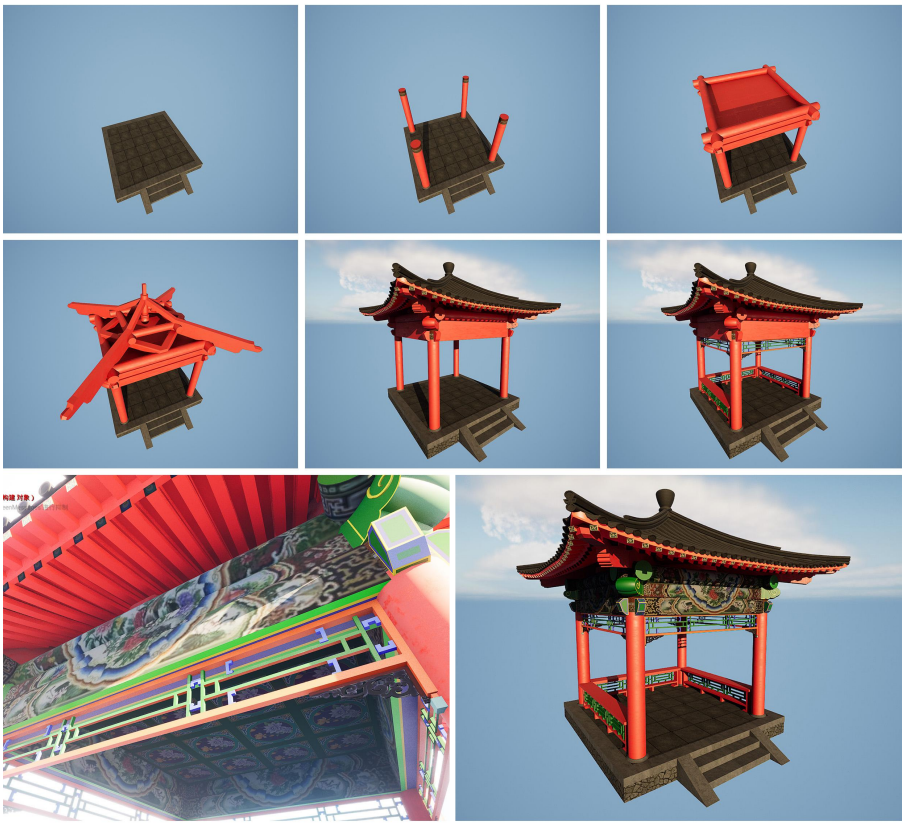

Figure 12: The square pavilion with ritual elements of grade 5(Baylor)

The second ritual model migration experiment is to test the migration capability of the ritual semantic model more widely, and we adopt the Japanese ancient-style main hall(Paine and Soper, 1981) as the base building. Through the automatic matching of the ontology design pattern described in Section 3, the PCG driver enhanced by the ritual system identifies the building elements of the same type that can match with the ritual constraints, and applied the three ritual elements: the foundation area,the roof beast and the colored painting in the Chinese style Lei ritual system. The attributes of the foundation and pillars mismatch with the Chinese Lei ritual system, and the other ritual elements are not expressed in the generation.

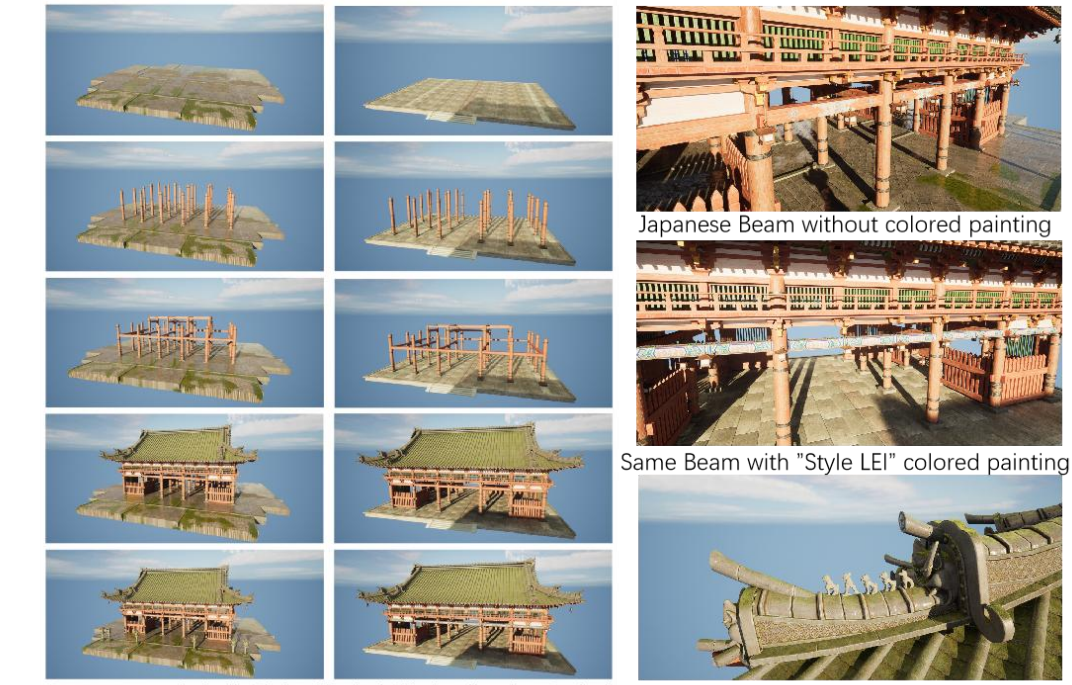

Figure 13: the migration of “Style LEI” ritual elements to a Japanese main hall

Based on the above experiments, the integrity of the basic design of the ritual model and the migration capability of the ritual system have been verified in this study.

4 DISCUSSION

The research in this paper basically achieves the preset goal. Compared with the previous researches, the 3 contributions of this paper lies in:

Firstly,we comprehensively provides a ritual semantic model that can be used for automatic generation of ancient buildings in game historical scenes.

This model has not been clearly defined in previous BIM researches, cultural heritage ontology researches, game ontology researches and ritual ontology researches. And meet the application requirements of semantic model of the game world (Kessing and Tutenel et al., 2012): 1)Semantics should further support procedural generation; this allows designers to combine and integrate multiple existing technologies to generate a coherent and coherent whole. 2)Designers should be able to define physically sound game worlds; it should be possible to mathematically represent dependencies between object features.

Secondly, we designed the ritual semantic model to provide the loose coupling capability with the game environment and building system based on the ontology design pattern , making it easy to expand and migrate

We analyze the PCG semantic system and building semantic system in detail, define a suitable ritual semantic model, and further abstract the cross-cultural and cross-regional ritual semantic features. Through the ontology design pattern, we realize the decoupling among ritual semantic model, building semantics, PCG driver and specific games.

Thirdly,through the analysis of the ritual semantic system of Style Lei, the experimental verification of the ritual semantic model is carried out, and the migration capability of the ritual semantic model is proved by comparison.

Ritual elements have abstract consistency and concrete complexity. We analyze in detail the ritual semantic system of Chinese style Lei buildings, and establish 4 types of ritual constraints and building element operation interfaces, which can be migrated to building elements in other countries or other culture, for example, a Japanese main hall is ritualized in the experiment by Chinese style Lei ritual elements.

Considerations for future work include the followings:

Firstly, a lightweight semantic model of in-game rituals can be further studied.

We suppose that heavy, complex owl models of the ritual ontology must not be used to accomplish the game design tasks. Because in the experiment, we found that the ritual semantic model(stored in xml format) defined based on Industry Foundation Classes (IFC) (Pauwels and De Meyer et al., 2011) or BOT(Rasmussen and Lefrançois et al., 2021) is not convenient to load. On the one hand, there is a lot of redundant mark data, which takes up a lot of storage space. On the other hand, such semi-structured text is quite inefficient for real-time lookup and matching in Unreal's blueprint system while may be more suitable for web semantic models(Sinclair and Lewis et al., 2006). In fact, it is entirely possible to alternate to a lightweight semi-structured data format such as JSON, but this format is very poorly for human to read or for web crawler to traverse. This aspect can be further researched.

Secondly, the ritual semantic model can be further extended to other countries and eras.

Style Lei is a typical official architectural system in China, with an obvious ritual system and clear feudal hierarchy. In the literature survey, we found that the expressions of ritual systems in architecture vary greatly from countries around the world(Paine and Soper, 1981; Etemad, 2017). The coordination and comparison of specific ritual building system in other countries is not conducted in this study. We also noticed that many countries have mixed rituals. For example, some regions in the middle Asia(Katz, 2005; Chan, 2020) in history had a mix of both the Islamic ritual system and the Chinese ritual system. How to express the diversity of the ritual elements still needs to be further explored.

Thirdly, the research on the ritual building community.

The ritual semantic model and its application in this paper are based on single buildings, but in fact, for example, the ritual building communities or ancient cities in China and Japan also have a ritual topographical layout as a whole to a flat area of tens of square kilometers, how to automate the generation of ritual building communities on a larger scale is an unfinished part of this study.

Fourthly, the artificial intelligence method of ritual semantic model auto-extraction .

The disadvantage of this study is that the analysis of the ritual semantic model requires a lot of literature review work by professionals, and it is still a high-cost and time-consuming task to refine a shareable ritual semantic model in present. In the future, combined with the latest NLP artificial intelligence model progress, we should conduct research on the automatic extraction of ritual semantics from a large number of historical documents, and provide ritual semantic model conveniently, accurately and comprehensively .

5 CONCLUSION

The automatic generation of ritual buildings is very important to the design of historical games, and this paper is a research on the whole chain from bottom to end aiming at this problem. Based on the in-depth analysis of the ritual system, a ritual semantic model with high mobility and compatibility is realized with the help of the ontology design

pattern, which is also a field application case of Interoperability in the frontier research of ontology. The models and experiments proposed in this paper and even the analysis of the ritual elements in the Chinese style Lei building system can provide useful references for related research.

Finally, the connotation of the ritual system is actually far more than a building field. Its application in games involves educators, art directors, game designers, screenwriters, software developers, graphics and sound designers. The research presented in this paper is only a small step in this general direction. We also believe that the automated design of historical games under ritual systems will inspire a great deal of interdisciplinary researches.

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